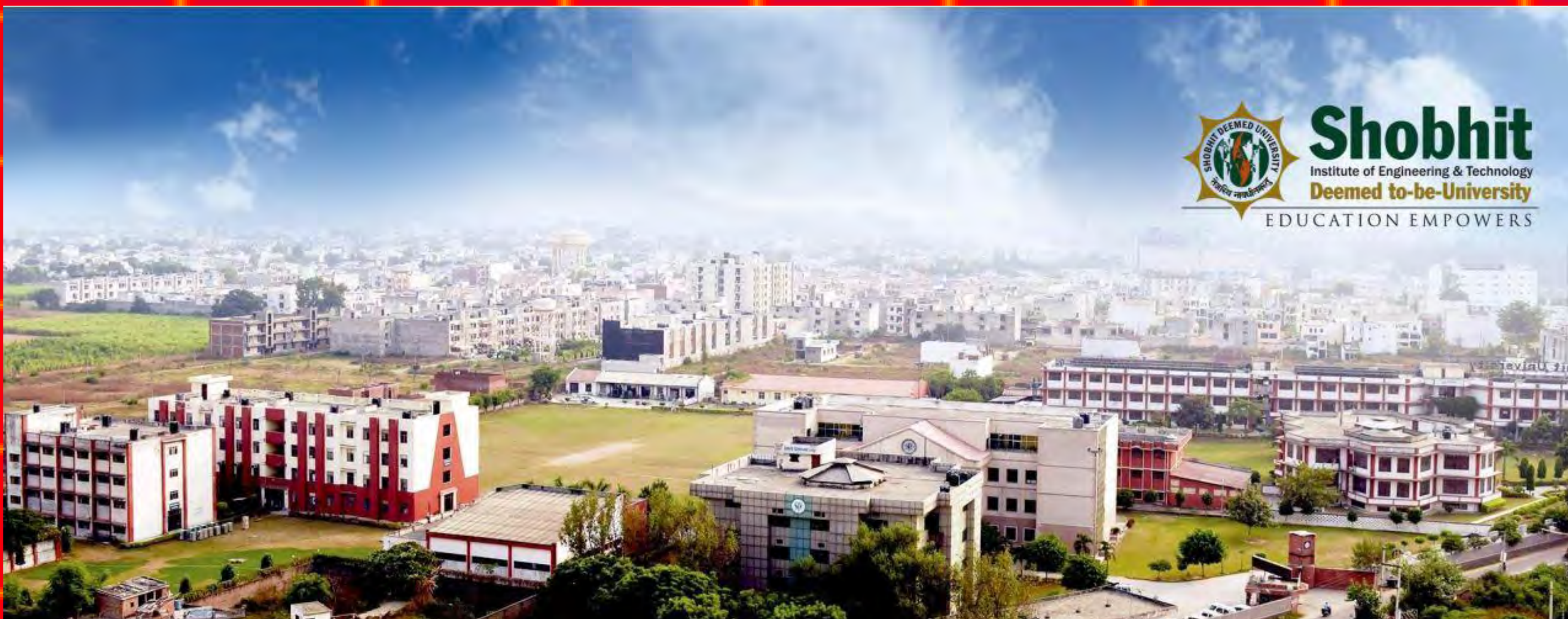
Two Port Networks

By

Mr. Aniket Kumar

Assistant Professor, Department of Electronics & Communication Engineering
Shobhit Institute of Engineering & Technology (Deemed to-be University)
NH-58, Modipuram, Meerut – 250 110, India



Chapter-5
Two port networks

A two-port network is a four- terminal circuit in which the terminals are paired to form an input port and an output port. Different models for two port networks are

Model Name	Express	In terms of	Defining equations
Impedance	V_1, V_2	I_1, I_2	$V_1 = z_{11}I_1 + z_{12}I_2$ and $V_2 = z_{21}I_1 + z_{22}I_2$
Admittance	I_1, V_2	V_1, V_2	$I_1 = y_{11}V_1 + y_{12}V_2$ and $I_2 = y_{21}V_1 + y_{22}V_2$
Hybrid	V_1, I_2	I_1, V_2	$V_1 = h_{11}I_1 + h_{12}V_2$ and $I_2 = h_{21}I_1 + h_{22}V_2$
Transmission	V_1, I_1	V_2, $-I_2$	$V_1 = AV_2 - BI_2$ and $I_1 = CV_2 - DI_2$

Hybrid Parameters

Every linear circuit having input and output terminals can be analyzed by four parameters (one measured in ohm, one in mho and two dimensionless) called hybrid or h Parameters. Hybrid means "mixed". Since these parameters have mixed dimensions, they are called hybrid parameters. Transistor is a three terminal device but for practical purpose it need four terminals two used for input & two for output.

Nomenclature for Transistor h Parameters

S. No.	h parameter	Notation in CB	Notation in CE	Notation in CC
1.	h_{11}	h_{ib}	h_{ie}	h_{ic}
2.	h_{12}	h_{rb}	h_{re}	h_{rc}
3.	h_{13}	h_{fb}	h_{fe}	h_{fc}
4.	h_{14}	h_{ob}	h_{oe}	h_{oc}

Long & Short Questions

Q.1. Explain the meaning of h-parameter of a transistor . Write down all h- parameters in different configurations. How will you obtain h- parameter of a transistor in CE configuration with the help of the characteristic curves ?

Or

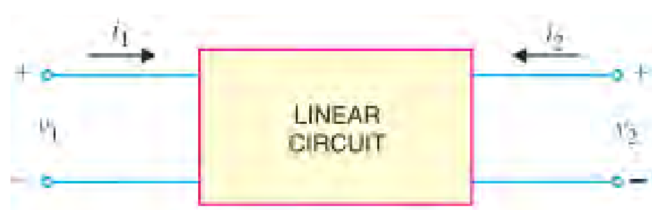
What do you understand by hybrid parameters of a transistor ? [Important]

Or

What is the significance of hybrid parameters ? Define them. How they are determined ?

Every linear circuit having input and output terminals can be analyzed by four parameters (one measured in ohm, one in mho and two dimensionless) called hybrid or h Parameters. Hybrid means "mixed". Since these parameters have mixed dimensions, they are called hybrid parameters.

Consider a linear circuit shown in figure. This circuit has input voltage & current labeled v_1 & i_1 and output voltage & current as v_2 & i_2 .



Hear both the inputs are assumed to flow into the

box.

Determination of h- parameters

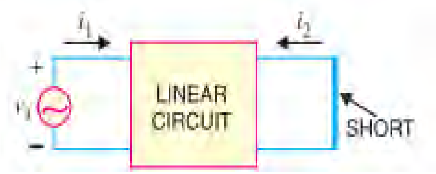
From the advance circuit theory voltages and currents in figure can be related by the following set of equations :

$$v_1 = h_{11}\, i_1 + h_{12}\, v_2 \qquad \ldots\ldots\ldots \text{(i)}$$

$$i_2 = h_{21}\, i_1 + h_{22}\, v_2 \qquad \ldots\ldots\ldots \text{(ii)}$$

- If we short- circuit the output terminals, we have $v_2 = 0$

  Applying these changes in above equations we have



$$v_1 = h_{11}\, i_1 + h_{12} \times 0$$

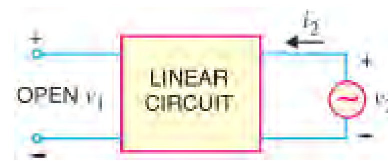
$$i_2 = h_{21}\, i_1 + h_{22} \times 0$$

$$\therefore \quad h_{11} = v_1 / i_1 \ \text{ for } v_2 = 0$$

$$h_{21} = i_2 / i_1 \ \text{ for } v_2 = 0$$

- If we open the input terminals, we have $i_1 = 0$

  Applying these changes in above equation (i) & (ii) we have



$$v_1 = h_{11} \times 0 + h_{12} v_2$$

$$i_2 = h_{21} \times 0 + h_{22} \times v_2$$

$$\therefore \quad h_{12} = v_1 / v_2 \text{ for } i_1 = 0$$

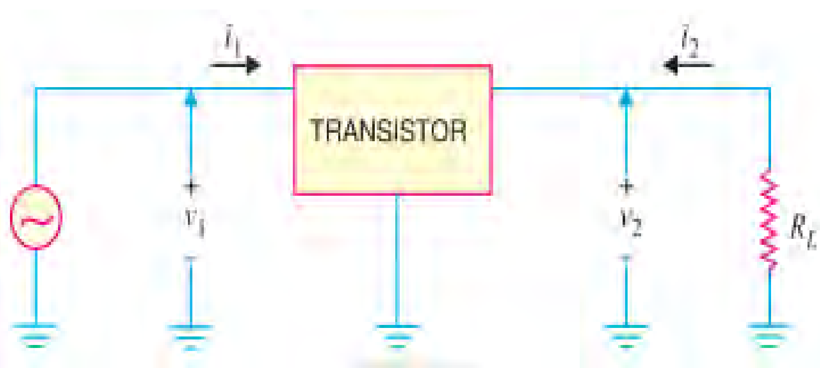
$$h_{21} = i_2 / v_2 \text{ for } i_1 = 0$$

Q.2. Define h- parameter for different configuration of a transistor . How are these determined experimentally ? Draw the hybrid equivalent circuit for any one configuration .

For definition refer to Q.1.

Hybrid equivalent circuit of a transistor

For small a.c. sigals, the transistor behaves as a linear device because the output a.c. signal is directly proportional to the input a.c. signal. Under such circumstances, the a.c. operation of the transistor can be described in terms of h



parameters.

- To describe the external behavior of transistor amplifier four quantities are required , these are v_1, i_1, v_2 and i_2 .These voltage & current are related as the following equations :

$$v_1 = h_{11} i_1 + h_{12} v_2 \qquad \text{……… (i)}$$

$$i_2 = h_{21} i_1 + h_{22} v_2 \qquad \text{……… (ii)}$$

- The values of h parameters of a transistors will depend upon the transistor connection (i.e. CB , CE or CC) used.
- The values of h- parameters depend upon the operating point. If the operating point is changed , parameter values also changes.
- The notation v_1 ,i_1, v_2 and i_2 are used for general circuit analysis. In a transistor amplifier, we use the notation depending upon the configuration in which transistor is used. Thus for CE arrangement.

  $v_1 = V_{be}$; $i_1 = I_b$; $v_2=V_{ce}$; $i_2=I_c$.

  Here V_{be}, I_b , V_{ce} & I_c . are the rms values .

Nomenclature for Transistor h Parameters

S. No.	h parameter	Notation in CB	Notation in CE	Notation in CC
1.	h_{11}	h_{ib}	h_{ie}	h_{ic}
2.	h_{12}	h_{rb}	h_{re}	h_{rc}
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Transistor Circuit Performance in hParameters

(i) **Input impedance** : The general expression for input impedance is

$$Z_{in}= h_{11}- (h_{12}h_{21})/ (h_{22}+ 1/ r_L)$$

For CE Configuration

$$Z_{in}= h_{ie}- (h_{re}h_{fe})/ (h_{oe}+ 1/ r_L)$$

Similarly , expressions for input impedence in CB & CC arrangements can be written.

(ii) **Current gain :** The general expression for current gain is

$$A_i = h_{21}/(1+h_{22}r_L)$$

For CE Configuration

$$A_i = h_{fe}/(1+h_{oe}r_L)$$

(iii) **Voltage gain :** The general expression for voltage gain is

$$A_V = -h_{21} / [Z_{in}(h_{22} + 1/ r_L)]$$

For CE Configuration

$$A_V = -h_{fe} / [Z_{in}(h_{oe} + 1/ r_L)]$$

(iii) Output impedance : The general expression for output impedance is

$$Z_{out} = [h_{22} - h_{21}.h_{12} / h_{11}]^{-1}$$

For CE Configuration

$$Z_{out} = [h_{oe} - h_{fe}.h_{re} / h_{ie}]^{-1}$$

Q.3. Explain two Port network & Y-parameters of a transistor.

Related Short Answer Questions
(i) Explain Y-parameter of a transistor .

Two port network explained in Q- 1 & Q-2

Admittance parameters or Y-parameters are the properties used in many areas of electrical engineering, such as power, electronics, and telecommunications. These parameters are used to describe the electrical behavior of linear electrical networks. They are also used to describe the small-signal (liberalized) response of non-linear networks.

The equations describing admittance parameters are

$$I_1 = y_{11}V_1 + y_{12}V_2$$

$$I_2 = y_{21}V_1 + y_{22}V_2$$

- If we short- circuit the output terminals, we have $v_2 = 0$

  Applying these changes in above equations we have

$$I_1 = y_{11}V_1 + y_{12} \text{ x } 0$$

$$I_2 = y_{21}V_1 + y_{22} \text{ x } 0$$

$$\therefore \quad y_{11} = v_1 / i_1 \text{ for } v_2 = 0$$

$$y_{21} = i_2 / v_1 \text{ for } v_2 = 0$$

- If we short the input terminals, we have $v_1 = 0$

  Applying these changes in above equation (i) & (ii) we have

$$I_1 = y_{11} \text{ x } 0 + y_{12}V_2$$

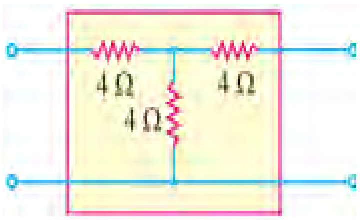
$I_2 = y_{21} \times 0 + y_{22} V_2$

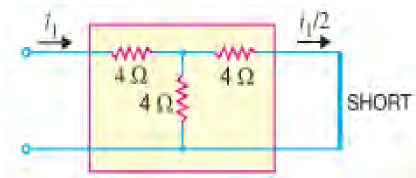
$\therefore \quad y_{12} = I_1 / v_2$ for $i_1 = 0$

$y_{22} = i_2 / v_2$ for $i_1 = 0$

Numerical

Q.1. Find the h- parameters of the circuit shown





Exp: Considering all the output terminals to be shorted , the input impedance under this condition is the parameter h_{11}

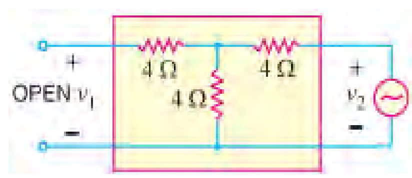
$\therefore h_{11} = 4 + 4 \;||\; 4 = 4 + 4.4/(4+4) = 6\Omega$

$\because$ Input current i_1 will be divided equally between ll connected resitances

$\therefore i_2 = -i_1/2 = -0.5 i_1$

$\because h_{21} = i_2 / i_1$

$\therefore h_{21} = i_2 / i_1 = -0.5\, i_1 / i_1 = -0.5$



In order to find h_{12} & h_{22} , with input open circuited we have

Under this condition , we have $v_1 = 4\,\Omega \,.\, V_2 / (4\,\Omega + 4\,\Omega) = 0.5 \times V_2$

$\because h_{12} = v_1 / v_2 = 0.5\, i_1 / i_1 = 0.5$

Looking into the output terminals with input terminals open, the output impedance is 8 Ω

$\therefore h_{22} = 1/8 = 0.125$ mho

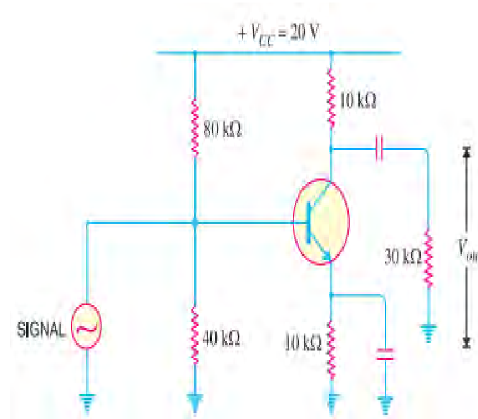
Q.2. Figure shows the transistor amplifier in CE arrangement. The h parameters of transistor are as under :

$h_{ie} = 1500\ \Omega$; $h_{fe} = 50$; $h_{re} = 4 \times 10^{-4}$; $h_{oe} = 5 \times 10^{-5}$ mho

Find (i) a.c. input impedance of the amplifier

(ii) voltage gain

(iii) output impedance.



Exp: The a.c. load r_L seen by the transistor is equivalent of the parallel combination of RC(= 10 kΩ & RL= 30 kΩ i.e. $r_L = 10 \times 30 / (10 + 30) = 7.5$ k Ω

(i) The input impedance looking into the base of transistor is given by :

$Z_{in} = h_{ie} - (h_{re}h_{fe}) / (h_{oe} + 1/r_L)$

Putting the respective values

$$Z_{in} = 1390\ \Omega$$

(ii)

Voltage gain i.e. $A_V = -h_{21} / [Z_{in}(h_{22} + 1/r_L)]$

Putting the respective values

$$A_V = -196$$

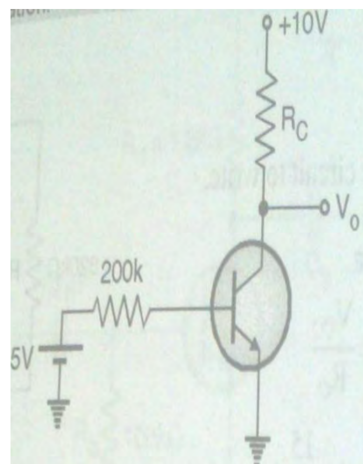
(iii) Output impedance i.e. $Z_{out} = [h_{oe} - h_{fe}.h_{re} / h_{ie}]^{-1}$

Putting the respective values

$$Z_{out} = 5.88\ K\ \Omega$$

Q.3. A silicon transistor with $V_{BE(sat)} = 0.8$ V , $\beta = h_{FE} = 100$, $V_{CE(sat)} = 0.2$ V is used in the circuit shown. Find the minimum value of R_C for which the transistor remains in saturation.

Exp: Given $V_{BE(sat)} = 0.8$ V , $\beta = h_{FE} = 100$ & $V_{CE(sat)} = 0.2$ V



Applying KVL at the input terminal , we have

$-5V + 200k.\ I_B + 0.8V = 0$

$\therefore I_B = 4.2 / (200 \times 10^3) = 21\mu A$

$\because I_C = \beta\ I_B = 100 \times 21\mu A = 2.1mA$

Applying KVL at the output terminal , we have

$-10 + R_C\ I_C + V_{CE(sat)} = 0$

$$\therefore R_C = (10 - 0.2) / 2.1mA = 4.667k\Omega \text{ Ans}$$